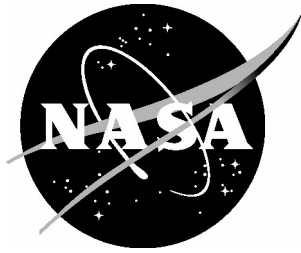


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NASA-Langley Research Center's Aircraft Condition Analysis and Management System Implementation

*Mark W. Frye and Roger M. Bailey
Langley Research Center, Hampton, Virginia*

*Artie D. Jessup
Science and Technology Corporation, Hampton, Virginia*

October 2004

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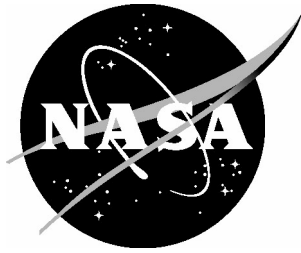
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National Aeronautics and
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Langley Research Center
Hampton, Virginia 23681-2199

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*Mark W. Frye and Roger M. Bailey Langley Research Center, Hampton, Virginia
Artie D. Jessup Science and Technology Corporation, Hampton, Virginia*

Abstract

This document describes the hardware implementation design and architecture of Aeronautical Radio Incorporated (ARINC)'s Aircraft Condition Analysis and Management System (ACAMS), which was developed at NASA-Langley Research Center (LaRC) for use in its Airborne Research Integrated Experiments System (ARIES) Laboratory. This activity is part of NASA's Aviation Safety Program (AvSP), the Single Aircraft Accident Prevention (SAAP) project to develop safety-enabling technologies for aircraft and airborne systems. The fundamental intent of these technologies is to allow timely intervention or remediation to improve unsafe conditions before they become life threatening.

A research flight test requirements document was developed, and a research system architecture was derived for the ARIES from those requirements. The requirements document included: a program overview, hardware requirements, software requirements, simulation requirements, and flight operations requirements. A combination of existing hardware and Commercial Off-The-Shelf (COTS) systems were selected, procured or fabricated, and installed to interface with ARINC provided equipment. This hardware/system include: cooling fans, Keyboard-Video-Mouse (KVM), KVM extender, 5 volt power supply, and interface panels.

LaRC's Boeing 757-ARIES with its Transport Research System (TRS) is a one-of-a-kind national asset with unique capabilities to serve NASA's research programs to improve the safety and efficiency and enhance the capacity and operational needs of the national air traffic system. The ARIES was integrated with the onboard ACAMS prototype for flight-testing, and is currently conducting/collecting research data. The resulting system is meeting NASA Langley's flight-research SAAP goals, and is enhancing the use of the latest technology in developing aircraft safety prediction.

Introduction

Established by inputs from researchers, implementers, and managers, a Research System Flight Test Requirements Document was written which institutes requirements for a general research system to be installed onboard NASA's ARIES. The document specifies the following four objectives for the design of the research system:

1. Demonstrate the functionality of the onboard ACAMS in an operationally realistic setting.
2. Diagnose and prognose the health state of selected aircraft subsystems (e.g., the main landing gear, wheels, and brakes, fuel system, or autoflight system) of the NASA ARIES flying laboratory.

3. Collect and archive flight and sensor data for further ACAMS design enhancements.
4. Deliver health messages to the ground.

The ACAMS flight experiment is a “ride-along” experiment onboard ARIES. This designation allows no special flight requests, but permits ACAMS to receive the required ARINC-429 aircraft data via ARIES’ communication channels using SCRAMNet and wire integration unit (WIU) without transmit authority to the SCRAMNet ring. The integrated ACAMS consists of an onboard system for sensing and real-time diagnostics and prognostics, and a ground-based system (off-board ACAMS) for longer-term diagnostics and prognostics. During flight, the onboard ACAMS segment gathers and stores as much flight data as allowable given onboard capacity constraints. The onboard ACAMS simultaneously analyzes immediate fault detection, diagnosis, and prediction. Health messages are relayed to the ground via an onboard data link. The data captured by the onboard ACAMS during the flight and onboard diagnostic session history will be archived and downloaded to the off-board ACAMS analysis segment. The off-board ACAMS processor will be used to further resolve faults detected during flight or to predict upcoming faults in order to assist in maintenance scheduling. The ACAMS research system hardware architecture block diagram is shown in Figure 1.

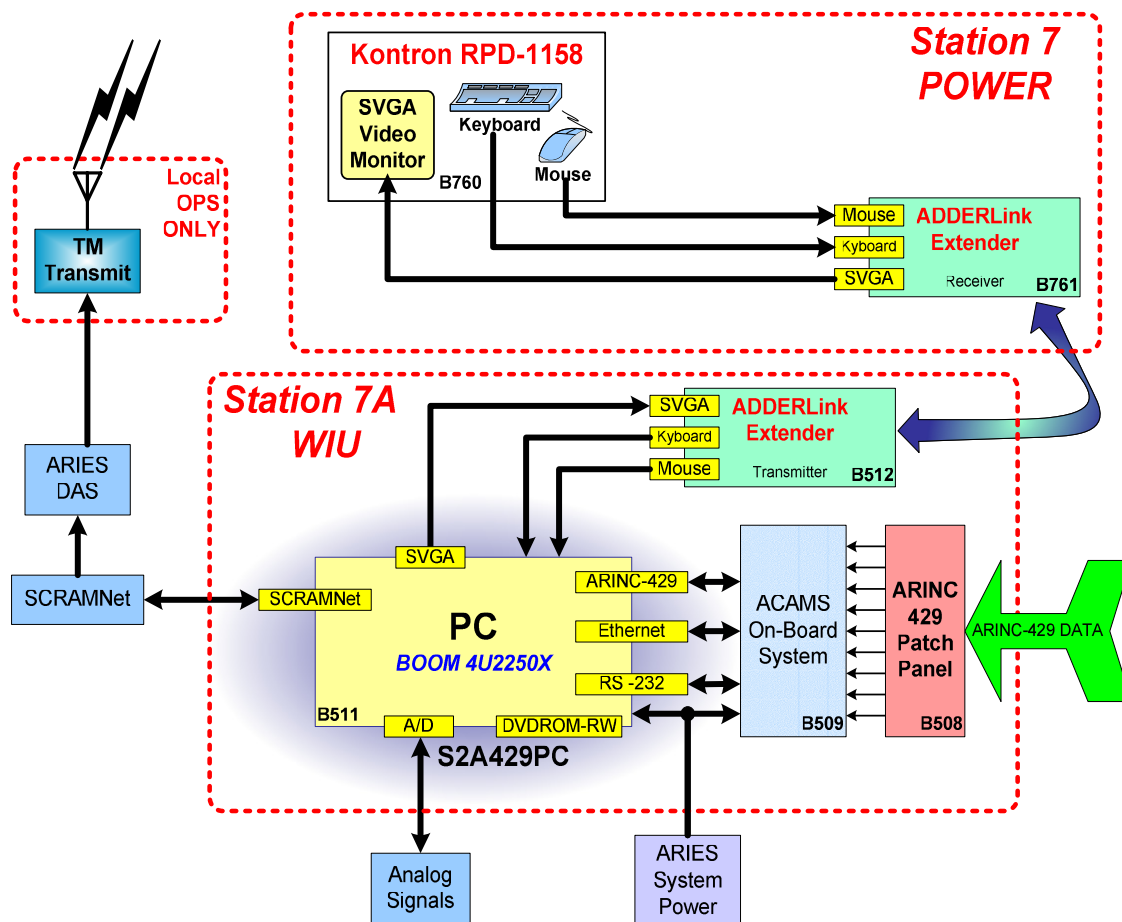


Figure 1. ACAMS Research System Block Diagram

The NASA-LaRC B757 ARIES Aircraft

LaRC's B757-ARIES with its Transport Research System (TRS) is a one-of-a-kind national asset with unique capabilities to serve NASA's research programs to improve the safety and efficiency and enhance the capacity and operational needs of the national air traffic system. The TRS baseline system includes 10 major subsystems, which are contained in research pallets that enable onboard system operators to monitor and interface with the subsystem functions. These subsystems include monitoring Flight Controls, Flight Management, an Onyx multi-CPU computer, the FlightMain software system, TRS Power, the I/O Concentrator, The Data Acquisition System, the Data Processing and Display System (DPDS), the video distribution and recording system, and the technology transfer area (TTA). The TRS includes a high-speed SCRAMNet ring and an Ethernet ring. Typically, as many as 2 or 3 independent research systems are connected to the TRS for joint missions or a series of flight research tests. The TRS includes personal computers for subsystem monitoring at each pallet as well as multi-mission computers connected to each independent research project subsystems.

ACARS or Aircraft Communications Addressing and Reporting System is an air/ground network which enables aircraft to function as mobile computer terminals linked to a ground-based command and control management system. Information collected from sensors onboard ACARS-equipped aircraft is automatically transferred by VHF radio link to ACARS ground facilities. It is then relayed via the ground stations to a central computer processor where the data is converted to inter-airline operational messages. Because there is not an ACARS (Aircraft Communications Addressing and Reporting System) aboard the ARIES aircraft, ACAMS messages will be sent to the ground via the ARIES' existing telemetry system. ACAMS messages will be placed at a predetermined location on the SCRAMNet and accessed through the telemetry system



Figure 2. NASA-LaRC B757 ARIES Aircraft

during flights in the LaRC local flight area (within approximately 100 nautical miles maximum at altitude) only. The ACAMS communications functions will be validated by evaluating the data received at the ground station or analyzing messages placed on the SCRAMNet for transfer to the ground. Future research includes ACAMS and ACARS performing together to facilitate aircraft maintenance needs.

ACAMS Implementation Scope

The scope of the 2003 ACAMS Flight Test Implementation Team was to coordinate the development of an implementation plan that satisfied all research requirements. This plan consisted of the development of all installation drawings, the flight hardening and environmental testing of equipment as necessary, and the purchasing of support hardware as needed. The proper planning of the project was conducted in the preparation of the implementation schedule, this included all lab testing and hardware installation onboard ARIES. The Implementation Team was also responsible for ground testing the hardware, as well as, supporting all flight tests.

Description of ACAMS Research System

Research Equipment

The system architecture was presented to a Critical Design Review Panel and was approved for installation on the B-757 Airborne Research Integrated Experiments System (ARIES) airplane. Initially the team agreed to purchase Commercially-Off-The-Shelf (COTS) equipment where available and without disturbing research capabilities.

Due to real estate constraints, ACAMS was regulated to be divided onto two adjacent ARIES stations, station 7 (Power) and station 7A (WIU). This delegation posed a communications problem, how could the ACAMS operator communicate with the ACAMS computer and ACAMS prototype? The implementation team agreed to incorporate a KVM (keyboard/video/mouse) extender system. COTS equipment was researched and an AdderLink KVM extender system was purchased. On station 7A an AdderLink KVM extender transmitter was installed and on station 7 an AdderLink KVM extender receiver was installed. This allowed the ACAMS operator the ability to communicate with the ACAMS computer to a distance of up to 700 feet. Additional ACAMS hardware on station 7 consisted of a Kontron KVM (COTS), the extender 5-volt power supply (existing), and interface panel (fabricated). ACAMS hardware installed on station 7A included the ACAMS chassis consisting of the mounting plate and tray and the ACAMS onboard prototype system, the ACAMS computer labeled the SCRAMNet-toARINC-429 PC (S2A429PC) system, the interface panel, and pallet cooling fans. Additional cooling fans were necessary due to non-existing forced airflow internal to station 7A.

The ARINC provided ACAMS onboard prototype is an avionics unit, developed in accordance with commercial transport standards, that provides integrated health management of selected aircraft subsystems. The S2A429PC provides the linkage between the ACAMS onboard prototype system and the ARIES DAS as well as storage devices for system data download. Figure 3 provides a block diagram of the key

hardware elements and interconnections that was needed on ARIES to enable the flight test.

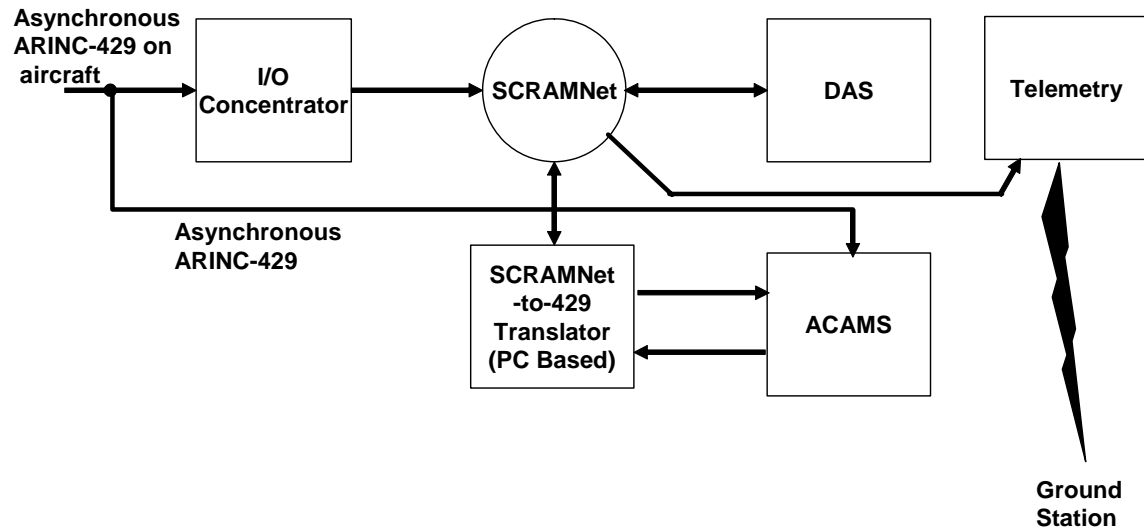


Figure 3. Key Hardware Elements and Interconnections for ARIES

Table 1 lists the hardware that was required to successfully attain the research objectives. All of the elements were existing NASA-LaRC equipment but the ACAMS pallet (station 7 & 7A) had to be determined.

Table 1. Required Hardware Elements

Element	Description
ADC-L, R	Air Data Computer Left and Right
EICAS-L, R	Engine Indicating and Crew Alerting System Left and Right
FCC-L, C, R	Flight Control Computer Left, Center, and Right
FSEU	Flap/Slat Electronics Unit
FQPU-L, R	Fuel Quantity Processing Unit Left and Right
ILS-L, C, R	Instrument Landing System Left, Center, and Right
IRU-L, C, R	Inertial Reference Units Left, Center, and Right
FMC-L, C, R	Flight Management Computer Left, Center, and Right
TMC	Thrust Management Computer
Telemetry	DAS Telemetry System
SCRAMNet ring	Provide information exchange between the Onyx, S2A429PC, the data links (FMS/VME), and the data recording system (DAS)
DAS	Record test data
I/O concentrator	Provide gateway to/from the SCRAMNet ring for GPS and other B-757 busses
DAT drive	Record playback data and install research software modifications on Onyx computer
ACAMS Pallet	Hold ACAMS onboard prototype, S2A429PC, and associated peripherals

As delivered to NASA, the ACAMS computer, S2A429PC included: a SCRAMNet adapter allowing access to SCRAMNet for monitoring of non-ARINC-429 parameters and an ARINC-429 interface providing data bus communication to/from the ACAMS onboard prototype system.

Additional hardware was procured/fabricated by NASA for ARINC provided equipment (S2A429PC & ACAMS Onboard Prototype). This hardware improved the functionality and allowed ease of operation during flight tests. A 24-channel A/D (analog-to-digital) board was purchased allowing 24 analog signals to be recorded. These signals consisted of 8 antiskid valve current sensor inputs, 8 brake pressure sensor inputs, and 8 wheel speed sensor inputs, which were otherwise unobtainable. Also, a 19" rack adapter was designed and fabricated providing hardware mounting for the ACAMS Onboard Prototype module. Figure 4 shows the design of the rack adaptor.

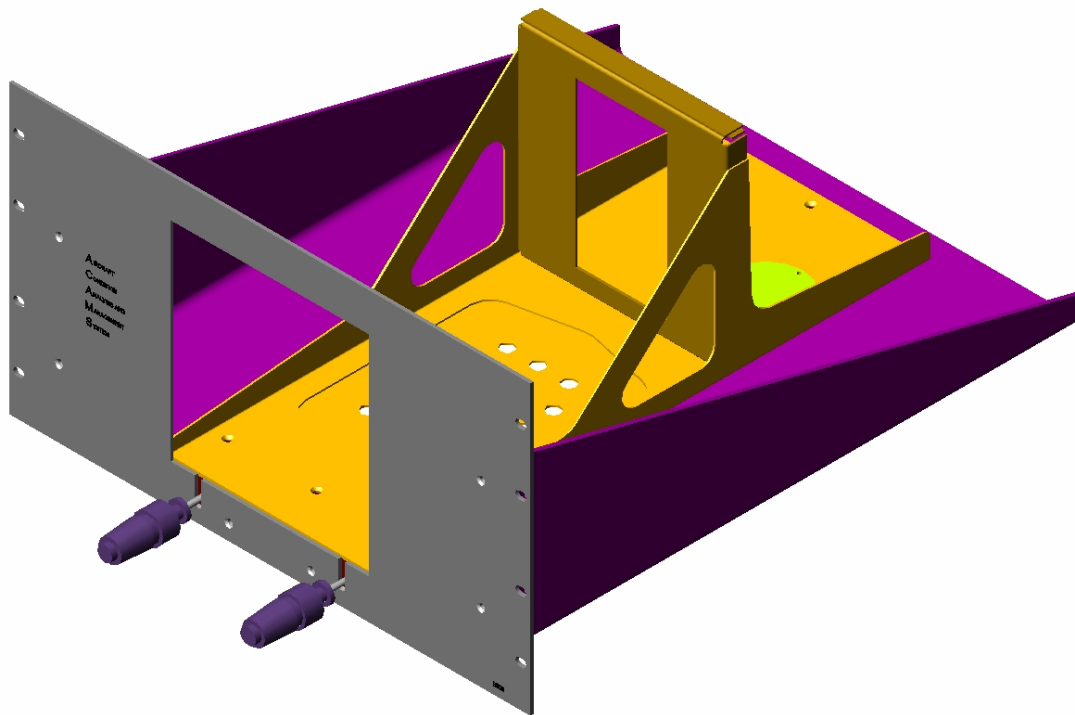


Figure 4. ACAMS Prototype Rack Adaptor Chassis

All hardware was fully documented in accordance with project guidelines and Langley Management System (LMS) procedures. These procedures include the Experimental Systems Work Request (ESWR) procedure LMS-CP-0909 Revision: C, utilizing Langley form LF-436 and the Aircraft Work Order (AWO) procedure LMS-CP-0910 Revision: A, utilizing Langley forms LF-432 and LF-433.

Environmental protection was provided for all hardware installed. This protection assures that the equipment is operated in an environment consistent with manufacturer specifications for thermal, vibration, pressure, and electromagnetic interference (EMI) boundaries. All equipment was presented before the Flight Operations Environmental Test Team and approved for installation.

ARINC-429 Data Bus

ARINC-429 is a specification, which defines how avionics equipment and systems communicate with each other. They are interconnected by wires in twisted pairs. The specification defines the electrical and data characteristics and protocols, which are used. Messages are transmitted at a bit rate of either 12.5 or 100 kilobits per second to other system elements, which are monitoring the bus messages. Transmission and reception is on separate ports so that many wires may be needed on the aircraft, which use a large number of avionics systems. ARINC-429 has been installed on most commercial transport aircraft including; Airbus A310/A320 and A330/A340; Bell Helicopters; Boeing 727, 737, 747, 757, and 767; and McDonnell Douglas MD-11. An ARINC-429 data bus uses two signal wires to transmit 32 bit words. The primary signal concentration for the ARIES subsystems' are ARINC-429 data busses which are for B-757 sensors (real or simulated), research computer, Data Acquisition Systems(DAS), and other experimental system signals of analog, digital, synchro and ARINC-429 types.

ACAMS requirements identified the ARINC-429 data busses needed. Table 2 lists those busses:

Table 2. ARINC-429 Bus Access Requirements

Bus	Description
ADC-L	Air Data Computer – Left
ADC-R	Air Data Computer – Right
EICAS-L	Engine Indicating and Crew Alerting System - Left
EFIS	Electronic Flight Instrument System
FCC-C	Flight Control Computer - Center
FCC-L	Flight Control Computer - Left
FCC-R	Flight Control Computer - Right
FMC-C	Flight Management Computer - Center
FMC-L	Flight Management Computer - Left
FMC- R	Flight Management Computer - Right
FQPU-L	Fuel Quantity Processing Unit, Left
FQPU-R	Fuel Quantity Processing Unit, Right
FSEU	Flap/Slat Electronics Unit
GPWS	Ground Proximity Warning System
IRU- C	Inertial Reference Units - Center
IRU-L	Inertial Reference Units – Left
IRU-R	Inertial Reference Units - Right
MCP	Mode Control Panel (Autopilot)
TMC	Thrust Management Computer

Operator Workstation

An operator workstation is required to control and monitor the ACAMS research system. Located at station 7, the operator observes data rates for all ACAMS busses, as well as, computer usage, status, and problems. The workstation display is part of a Kontron RPD-1151 KVM. It is a 15-inch LCD TFT display with a pixel resolution of 1024 x 768. As stated earlier, space is an issue onboard ARIES and utilizing the Kontron RPD-1151 compact storage of 1U (1.75") of rack space allows for greater efficiency at station 7. The operator workstation is shown in Figure 5. The KVM communicates with the ACAMS computer via a COTS item called an AdderLink KVM extender. It is designed to transfer keyboard, video, and mouse signals over 700 feet using Category 5 twisted pair cable. The AdderLink system consists of a transmitter and a receiver unit that are connected together by the twisted pair cable. The receiver unit connects to the keyboard, monitor and mouse and the transmitter unit connects to the ACAMS computer.



Figure 5. Operator Workstation

Integration Testing

NASA-Langley personnel installed the research equipment and mounts onto replicated ARIES equipment racks in the Systems Development Branch's ground-based FSIL (Flight System Integrated Laboratory) for integration testing. This installation was completed after flight-hardening and quality-assurance inspection were finalized. Integration testing began once associated power, control, and interface wiring were complete. Initial tests were performed for all pallet mounted equipment. All mechanical and electrical components of ACAMS were inspected and approved by NASA-Langley flight quality-assurance personnel for safety-related defects. Those defects that were identified during the integration testing and inspections were documented and corrected prior to installation of the equipment in the aircraft.

After the laboratory integration testing was complete, the ACAMS research equipment was installed onboard ARIES. Additional aircraft power and interface wiring were completed and in-situ tests were performed using both external power and internal aircraft power. During these tests, communications between the ACAMS computer and onboard prototype system were tested; all data channels were confirmed to be

operational, and data was processed using the ACAMS computer and ARIES DAS. Additional wiring and communications problems were identified and corrected through this process. Pre-flight and operational procedures were developed for the complete ACAMS research system at the completion of these tests.

Flight Testing

A total of two Instrument Check Flights (ICF's) were flown and verified the proper operation of the ACAMS research system. All required signals were recorded during both flights and local telemetry data was recorded as required. These tests included the receipt of all necessary avionics data from ship's sensors to the ACAMS computer via the ACAMS prototype. All ACAMS communications operated smoothly with no interference with existing basic ship's data and avionics. The ACAMS system performed as designed during the ICF's, however additional software modifications are necessary and are being finalized by ARINC engineers. The ACAMS flight prototype box is shown in Figure 6. More flights are scheduled, when the ARIES resumes flight testing.

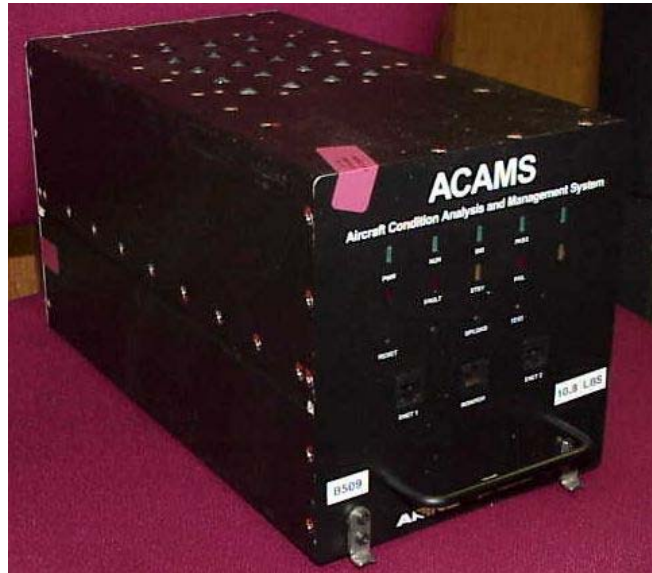


Figure 6. ACAMS Flight Prototype

Conclusion

The configuration of the Aircraft Condition Analysis and Management System has been designed, fabricated and successfully installed in the NASA-LaRC B757 ARIES aircraft. The ACAMS system includes nine hardware elements, which are: ACAMS Flight prototype, ACAMS computer (S2A429PC), AdderLink Extender transmitter, AdderLink Extender receiver, Kontron KVM, two interface panels, 5V extender power supply, and a 28VDC pallet fan for additional cooling. The net aircraft weight gain for all ACAMS modifications was 108.2 pounds installed on pallets 7 and 7A.

The NASA-LaRC ARIES aircraft is currently under a flight safety stand down; all ARIES flight tests have been postponed. The ACAMS flight software is being upgraded and tested by ARINC engineers that will enhance ACAMS capabilities for the future. The implementation of the ACAMS hardware has resulted in meeting NASA Langley's flight-research needs as part of NASA's Aviation Safety Program. This Single Aircraft Accident Prevention project is developing safety-enabled technologies for aircraft and airborne systems.

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